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DOE M&O Contractor Perspectives on Beyond Design Basis Event Analysis and Response

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HFIR serves a broad range of science and technology communities and will need to operate to at least 2040 until replacement capabilities are available

- **Very high flux** – available for neutron science in the world at $2.5X10^{15}N/cm^2/sec$
- **Fuel design** – breakthrough flux-trap design remains world class

173 Neutron Scattering and Material Science Publications in CY2011

Materials Irradiation Testing

- **Fusion Energy** – provides best available neutron spectrum for radiation damage testing on fusion components; collaboration between U.S. and Japan for over thirty years
- **Fission Energy** – research supporting next-generation commercial power reactors including accident tolerant fuel and reactor materials
- **National Security** – Neutron Activation Analysis supporting IAEA non-proliferation monitoring

1,021 Materials and NAA Irradiations in FY2011

Reliable Source of Unique Isotopes

- **Californium-252** – HFIR supplies 80% of the world demand, which is critical for industrial, defense, and energy uses
- **Berkelium-249** – used in the discovery of element 117 and the search for element 119
- **Plutonium-238** – the source of power for satellites and NASA's deep space missions
- **Selenium-75, Nickel-63, Tungsten-188** – supplier of industrial, homeland security, and medical isotopes

98 Commercial and Medical Isotope Irradiations in FY2011

Neutron Scattering

- **Cold Source**
  - Small-angle neutron scattering (2)
  - Cold triple-axis spectroscopy
  - Neutron imaging
  - Quasi-Laue Diffractometer
- **Thermal beams**
  - Triple-axis spectroscopy (3)
  - Powder diffraction
  - Single-crystal diffraction
  - Residual stress diffraction

1,300 Users conducted 730 Unique Neutron Scattering Experiments in FY2011

For more information go to http://neutrons.ornl.gov/facilities/HFIR/

HFIR reactor is used exclusively for research, it does not produce power

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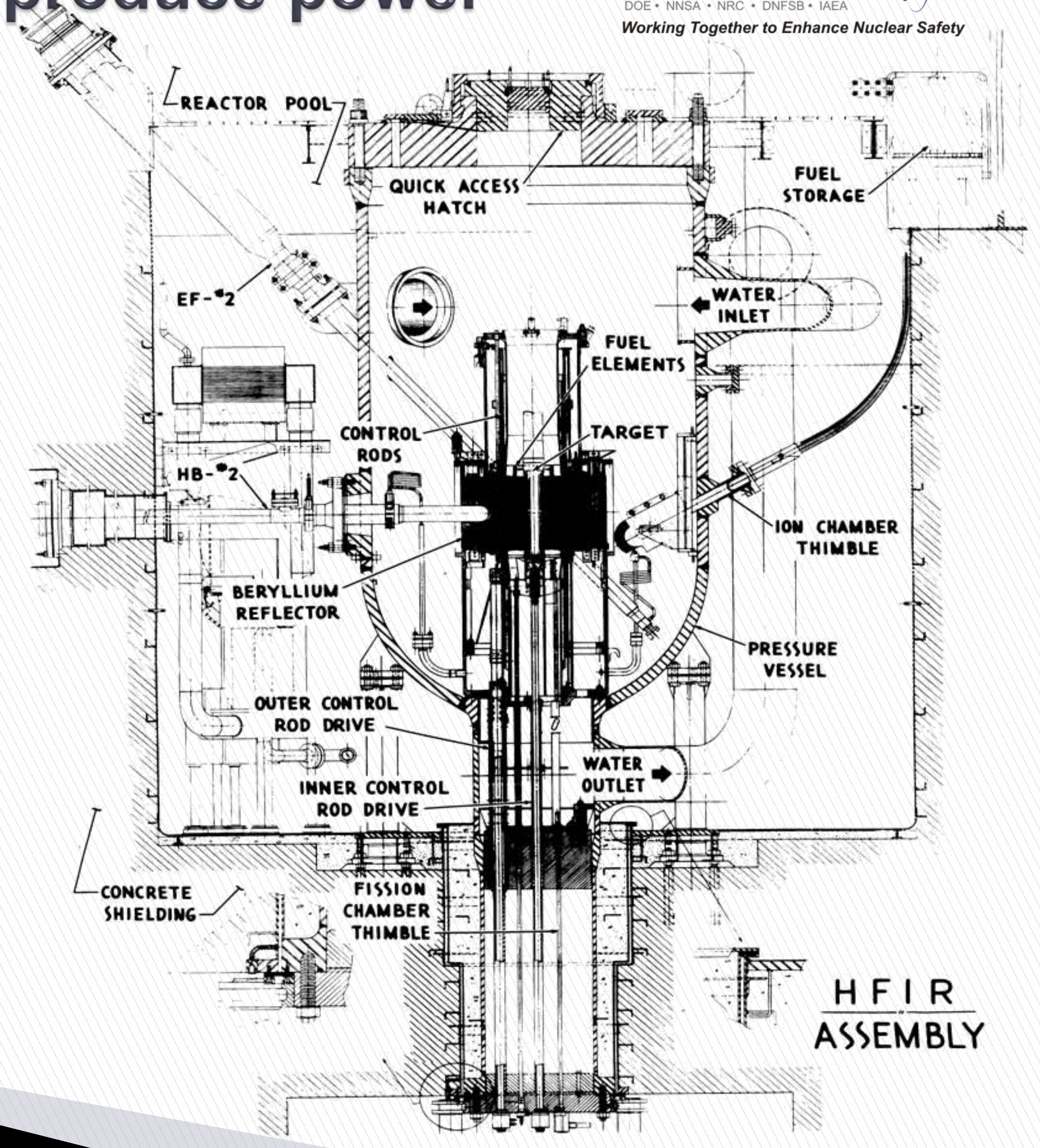
It has a peak thermal neutron flux of 2.5×10^{15} neutrons per square centimeter per second, which is the highest in the western world which is 50 to 100 times higher than cores of nuclear commercial power plants

The HFIR is a beryllium-reflected, light water-cooled and moderated flux-trap type swimming pool reactor that uses highly enriched uranium-235 as the fuel

A fuel cycle normally consists of full-power operation for approximately 23 days at 85 MW



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Scope of HFIR BDBE Pilot

Discussed the Documented Safety Analysis (DSA) evaluation of BDBEs

Considered the impact of Beyond Design Basis Events on HFIR Critical Safety Functions, verified via selected system walkdowns

Evaluated impact of extended station blackout (SBO)

Evaluated ORNL and HFIR emergency management capabilities considering:

- Impact to multiple facilities
- Loss of infrastructure capabilities
- Unavailability of mutual aid

Key differences between HFIR and a commercial LWR

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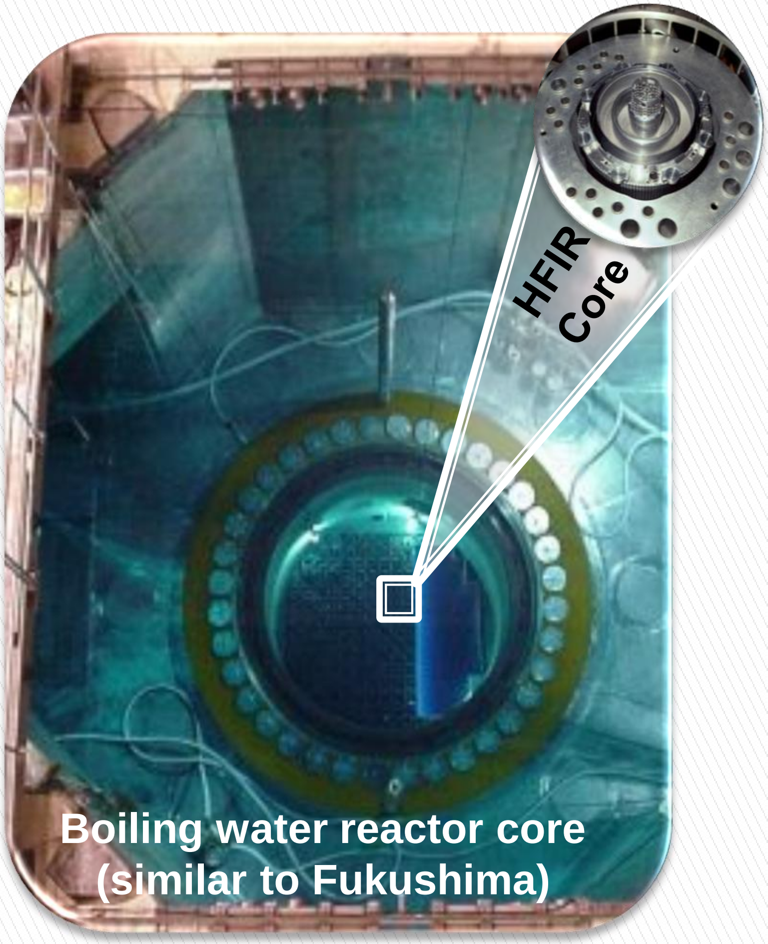
	FUKUSHIMA	HFIR
MASS OF CORE	On the order of 110,000 lb of uranium fuel and 50,000 lb of Zircaloy cladding	22 lb of uranium fuel and 200 lb of aluminum cladding
POST-SHUTDOWN HEAT REMOVAL	AC power or diesel generators needed to keep the reactor safe	Batteries provide all the cooling needed for 12 hours, and after that, no power for cooling is required at all
ULTIMATE HEAT SINK	Coolant must be pumped from a remote volume of water	The reactor is submerged in a pool capable of absorbing all the heat that the core will generate after shutdown
OPERATING TEMPERATURE	500 °F water must be cooled down to achieve a safe shutdown condition at low pressure	155 °F water is already at a temperature that will be safe at low pressure
GEOGRAPHY	Prone to severe earthquakes and location is susceptible to tsunami	Earthquake frequency/severity is less and no potential for tsunami; flooding from nearby rivers/dams does not threaten facility due to elevation



The pilot considered the impact of Beyond Design Basis Events on HFIR Critical Safety Functions

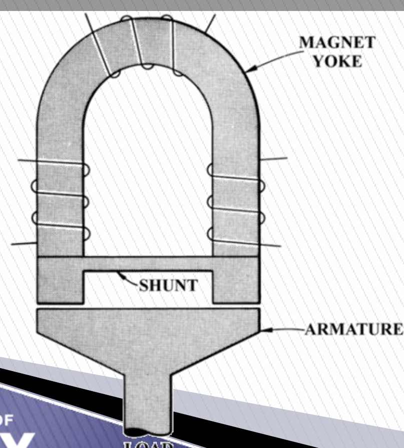
HFIR Critical Safety Functions	Beyond Design Basis Events
• Subcriticality • Core Cooling • Heat Sink • Containment/Confinement • Pool Water Inventory	• Seismic • Wind/tornado • Flooding • Ice/Snow & Ash cloud • Lightning • External Fire • Extended Station Blackouts

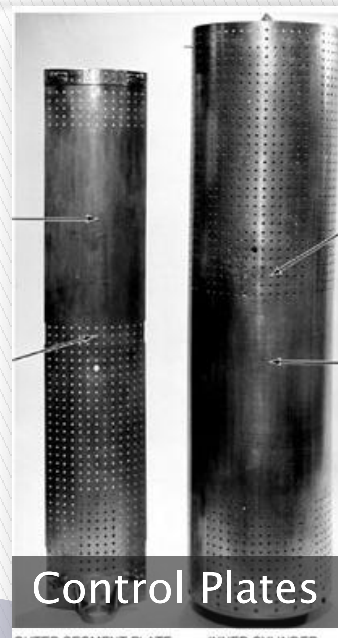
Subcriticality

Safety System

- The reactor instrumentation and safety system design indicate the emphasis placed on the importance of safety
- Three independent safety channels are arranged in a coincidence system that requires agreement of two of the three channels for a safety shutdown or scram of the reactor
- Reactor power control systems that are ‘separate from’ and ‘independent of’ the safety system

Rod Drive Magnet Actuator





Control Plates

Poison Injection Storage Tank

Core Cooling

Decay heat removal is provided by any one of 4 available DC-powered pony motors running at a reduced speed on battery power

Batteries provide all the cooling needed for 12 hours, and after that, no power for cooling is required at all

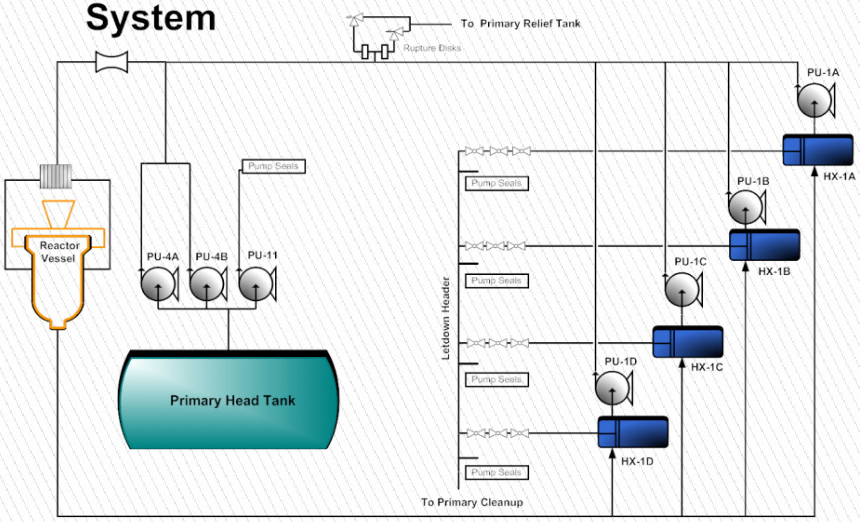
Pony motors are directly coupled to the main primary coolant pump motor shaft

During a LOCA vessel inventory provided by the pool-to-vessel check valve


Pony Motor


Pool to Vessel Check Valve

Primary Coolant System



Heat Sink

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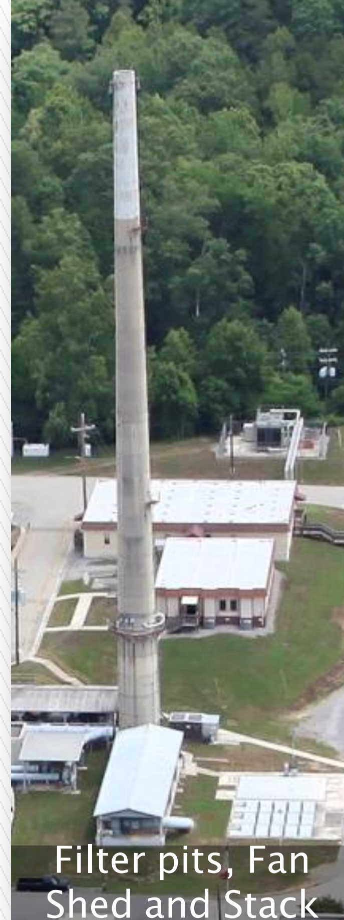
Secondary cooling not required for decay heat removal or spent fuel pool cooling

- Pool and piping have sufficient heat capacity to accommodate decay heat

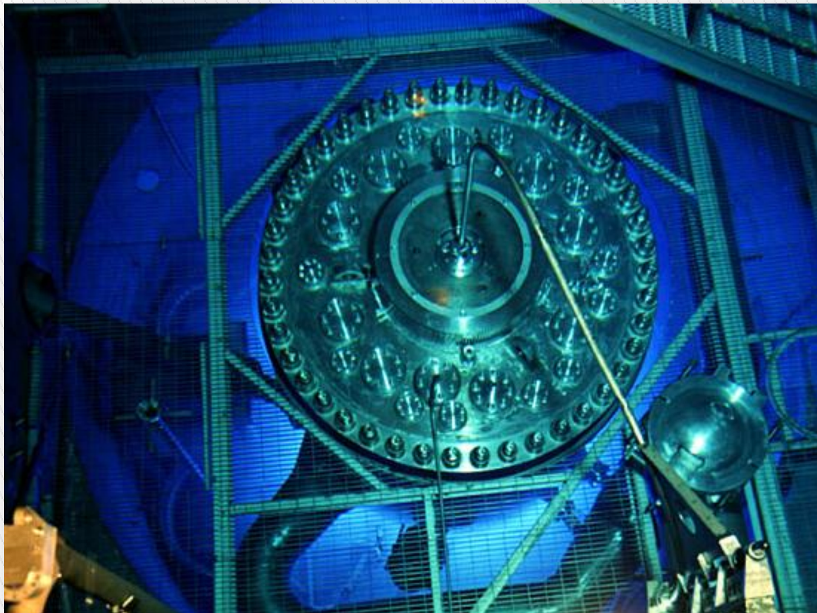
Containment/Confinement



Filter pits, Fan Shed and Stack

Confinement

- The Reactor Building Confinement System is a combination of structures and systems that maintains a constant negative building pressure, to prevent the uncontrolled release of airborne radioactivity to the atmosphere



Containment

- If high radiation levels are detected in the primary coolant water the reactor automatically scrams and block valve in the letdown lines and other lines going to the primary cleanup system are shut

SBHE Fan

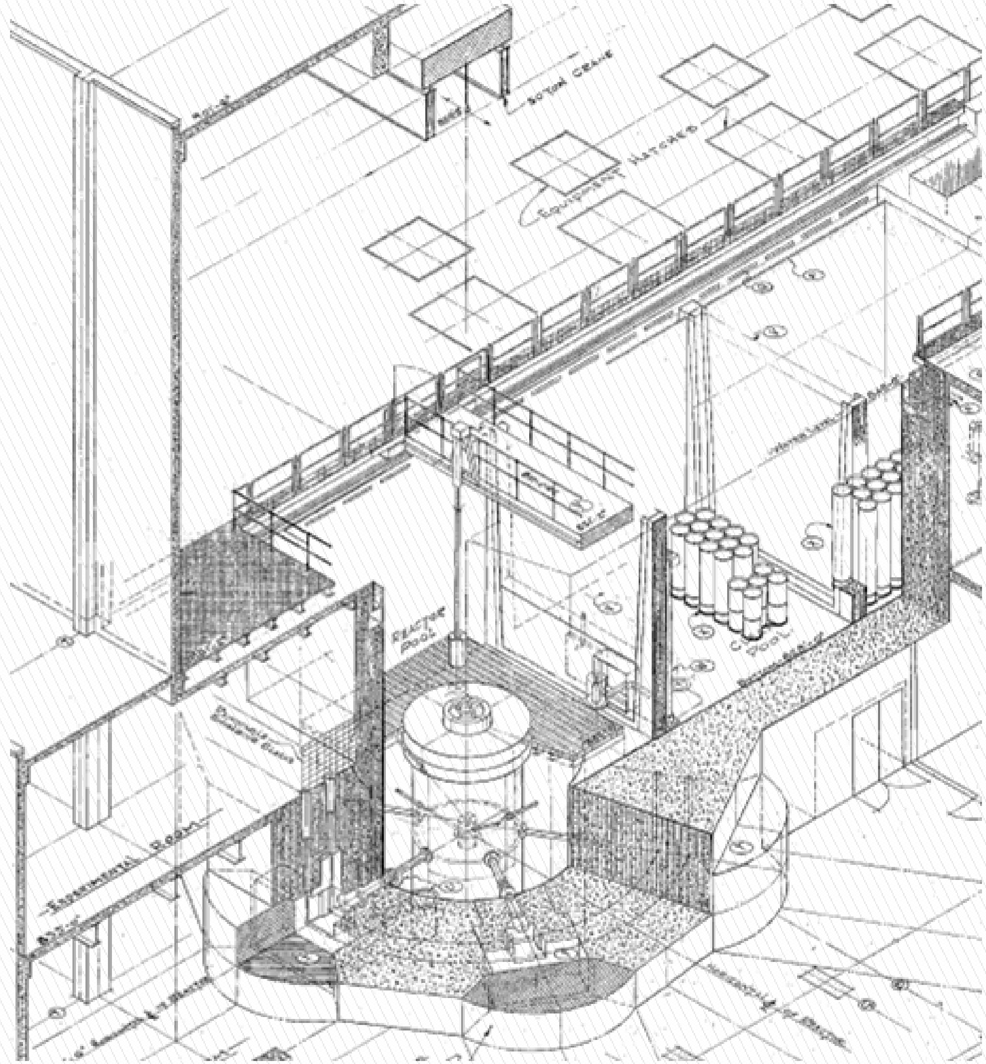
Pool Water Inventory

The HFIR design includes a large spent fuel storage pool with capacity to accommodate a loss of all AC power without boil off of the pool

The pools are built so a failure of the separation dam maintains enough inventory to keep fuel covered

Walls are 4’ to 8’ of reinforced concrete with a stainless steel liner

The emergency pool fill subsystem supplies process water directly to the pools in the event of a major unisolable leak



Beyond Design Basis Event impacts on Critical Safety Functions

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Seismic

A seismic event has the greatest potential to have an effect on the integrity and/or availability of all critical safety functions.

There is potential for enhancing the severe accident management process by including a water management plan to provide an alternate means of supplying water to the reactor and spent-fuel pools.

Wind/tornado

A wind/tornado event may result in loss of off-site power and loss of the on-site diesel generators. Although there is potential to affect confinement the pony motor batteries will remain available, therefore there is no impact on safe shutdown.

Flooding

Flooding resulting from seismically induced dam failure has been analyzed. The predicted high-level watermark is below the ground floor of the reactor building, therefore there would be no impact on critical safety functions.

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Beyond Design Basis Event impacts on Critical Safety Functions

Ice/Snow & Ash cloud

Failure of the HFIR building roof as a result of loading from ice, snow, or volcanic ash was evaluated and determined to be unrealistic.

Lightning

The worst-case scenario was assumed, that a lightning strike resulted in the loss of all off-site power, which the site is capable of withstanding with no adverse effects.

A lightning strike on the hydrogen supply to the HFIR Cold Source was also analyzed and was shown to not have an impact on safe shutdown.

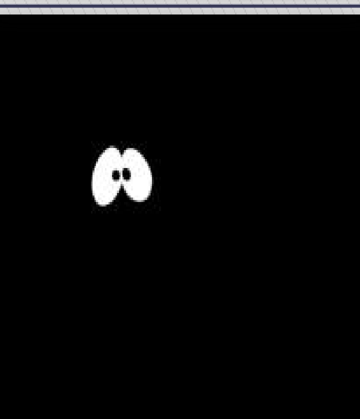
Beyond Design Basis Event impacts on Critical Safety Functions

External Fire

It was determined that the Operators would have sufficient time to conduct a safe reactor shutdown

This scenario indicated that it would be useful to have additional guidance regarding equipment and provisions for remote monitoring of CSFs during an evacuation.

Extended Station Blackout



HFIR relies on pony motors/battery banks for necessary core cooling, no core damage as a result of loss of off-site power. Batteries provide all the cooling needed for 12 hours, and after that, no power for cooling is required at all. If less than 12 hours of battery power assumed, core damage may occur; however, any fission products released would be contained within the primary coolant system

Outcomes of the HFIR BDBE Pilot

The evaluation confirmed that the HFIR safety basis adequately analyzes beyond design basis events

ORNL Emergency Management Program is robust and already incorporates BDBEs in the emergency management planning and response process

Areas for improvement in mitigating beyond design basis events include cases where:

- HFIR site is isolated
- HFIR site is evacuated

If HFIR site is isolated, conservation of resources will be key

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- Procedure for the operation of the pony motors has been revised to run the battery banks to exhaustion after meeting the 12 hour mission time
- Procedure for the operation of the instrument battery system has been revised to maximize available battery life
- Relocating one of the HFIR auxiliary emergency diesel generators to the HFIR site (previously both stored off site)
- Developing procedures and plans for the management of on-site water resources
- Evaluating use of pony motor battery bank jumper cables

Extended evacuation of the HFIR site requires additional planning

- Need to develop clear guidance to the HFIR Emergency Director for sending non-essential personnel home
- Need to develop an asset protection walk-away strategy for cold source
- Evaluate the enhancement of remote monitoring capabilities for HFIR critical safety function parameters, including backup power
- Development of coordinated response for impacts to co-located facilities (e.g., REDC & HFIR in Melton Valley)

Any questions?